

Documenting Fine-Sediment Import and Export for Two Contrasting Mesotidal Flats

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Award Number: N00014-10-1-0214

LONG-TERM GOALS

The general goal of this project is to examine the seabed, quantitatively document the fluxes of fine sediment (over different time scales), and thereby validate localized measurements and numerical models of sediment transport.

OBJECTIVES

The specific objectives are to:

- a) document changes in bed elevation (deposition, erosion) on time scales intrinsic to the driving forces; e.g., tidal and wind-driven currents, local waves, river discharge, and interannual variability;
- b) measure net accumulation rates over decades at many sites to calculate fine-sediment budgets for both Willapa and Skagit tidal systems;
- c) examine sedimentation at sufficient locations to characterize spatial variability of grain size and its vertical stratification.

APPROACH

The tidal-flat sedimentation in Willapa mud flats and Skagit sand flats has been contrasted, with a focus on understanding the import of mud to the Willapa flats and the export of mud from the Skagit flats. This has involved development of sediment budgets to document quantitatively the fate of muddy sediment, and also includes investigation about the variability of sedimentation over several time scales. Because UW is located near the Willapa and Skagit tidal flats, we helped provide logistical support to colleagues traveling long distances to work in these areas. We have acted as the primary contact for the federal, state and county regulatory agencies. As coordinator for the Tidal Flats DRI, I helped organize a group workshop in Boston during Oct 09, a special session at AGU Ocean Sciences during Feb 10, and a special issue of Continental Shelf Research (to be final in FY11).

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE 2011		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE Documenting Fine-Sediment Import and Export for Two Contrasting Mesotidal Flats				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) School of Oceanography University of Washington Seattle, WA 98195-7940				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES FY2010 Annual Reports of S & T efforts sponsored by the Ocean Battlespace Sensing S & T Department of the Office of Naval Research., The original document contains color images.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 6	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

WORK COMPLETED

For FY10, a series of intense sampling surveys were completed in Willapa Bay during Jan-Mar 10. Weather difficulties caused repeated attempts to finish the work. Monthly trips were undertaken throughout the year for time-series sampling (and instrument maintenance as part of collaborative sediment-transport studies). The mobile barge was used in shallow water, especially for vibracore sampling. In addition, it was used for semi-diurnal time-series observations at fixed locations (using its jack-up capability). All cores (tidal and seasonal time-series short cores, and long vibracores) were examined by x-radiography and subsampled for radiochemical and grain-size analyses.

Small boats were used to sample the Skagit tidal flat, with a special effort to get vibracores from the area receiving sediment from the South Fork of the Skagit River. In addition, a final cruise on the R/V Barnes was undertaken to the subtidal areas of the dispersal system, adding cores at the southern end of Saratoga Passage to close the sediment budget.

RESULTS

Willapa Bay – Observations on the southern Willapa flats during FY 10 confirmed the observations from FY09. Much more sediment is transported and deposited in channels during winter than during summer. Once again, the floors of secondary tidal channels (e.g., tributaries to Bear Channel) showed a dramatic change between winter conditions (March, 2010) and summer conditions (Sep, 2010)(see Fig.1). The muddy channel bottoms with physical stratification (individual laminae 1-3 cm thick) gave way to a shell-hash pavement in summer, as in FY09. The presence of a shell-hash layer ~25 cm below the winter channel bed suggests that seasonal input and removal of muddy sediment (tens of centimeters thick) is a regular occurrence.

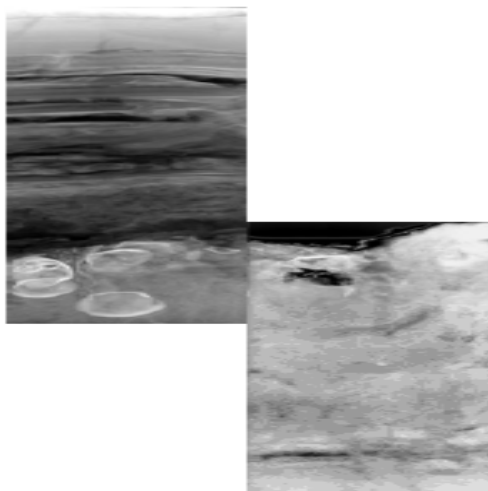


Figure 1 – Channel deposits in Willapa Bay at end of winter conditions (Mar 2010) – left side. It shows 25 cm of fresh stratified sediment (not there at end of summer 2009), with shell hash at base. Right side shows channel condition at end of summer conditions (Sep 2010), with shell-hash layer at surface. These distinct seasonal changes were also observed during 2008-2009.

^7Be (half life 53 days) is an indicator of recent sediment input from a terrestrial source. ^7Be was again found in the surficial seabed after winter flooding, and indicated import of sediment likely from local streams. We are now considering the possibility that some atmospheric deposition of ^7Be occurs directly onto the flat, and may impact the interpretation of the signal. Numerous cores (~60) have been collected for measurement of sediment accumulation rates by ^{210}Pb geochronology (half life 22.3 y). These have been used to create a preliminary budget for sediment accumulating on the tidal flat in southern Willapa Bay. The cores were collected with clear recognition of their location with respect to local morphology (e.g., channel, bank, flat), because spatial differences occur in sedimentary processes. Several ^{210}Pb signatures have been recognized, and our understanding of these has changed over the past year. The most common profile found on the flat surface is a logarithmic decrease in activity, commonly, beneath a surface mixed layer (indicative of intense bioturbation) as in Fig. 2. Accumulation rates on the flat surface are typically 1-2 mm/y, consistent with the local sea-level rise. Rates can reach 7 mm/y at some sites close to channels. Other areas near channel banks are erosional (e.g., cut banks). Most commonly, uniform excess ^{210}Pb is observed to extend deep into the seabed of physically stratified deposits on the banks of channels, and on channel floors during the winter.

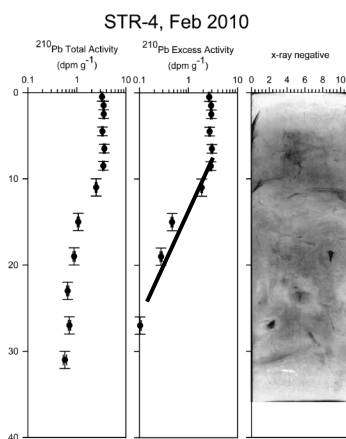


Fig. 2 – Typical core from southern Willapa flat surface. The ^{210}Pb profile indicates an accumulation rate of 1.4 mm/y, below a surface mixed layer (SML). The SML suggests intense bioturbation from benthic organisms, also reflected in the mottled sedimentary structure in the x-radiograph (negative). The steady-state accumulation rate indicated below the SML suggests that upward accretion is limited by the rate of local sea-level rise.

The present interpretation of sedimentary processes in southern Willapa Bay is that winter discharge from distant rivers provides sediment that is moved between flat and channel regularly on semi-diurnal time scales. During winter, this sediment resides mostly in the channels and on their banks. Through the summer, the continual exchange between the channels and flat allows biological processes to impact the fate of sediment. Likely, enhanced growth of eel grass and benthic algae causes decreases in boundary shear stress and increases in critical stress, respectively (from research of Wheatcroft and Wiberg), and this is the time when sediment is permanently placed on the flat surface for accumulation. The mass of muddy sediment temporarily residing in channels during the winter, approximately equals the total mass accumulating on the southern Willapa flat surface ($\sim 1 \times 10^4$ tons/y).

Skagit Bay – The surface of the Skagit tidal flats commonly has ripples associated with tidal currents and/or surface waves. These features demonstrate the dynamic and sandy character of the flats. Following high discharge events, ephemeral mud deposits are generally found several centimeters thick and containing ^7Be , especially near the North Fork and associated tidal channels. Despite the input of muds, no thick or extensive mud deposits have been found buried within the tidal flats. Thin (~1-2 cm) laminae are found in vibracores (Fig. 3), and these contain both ^{137}Cs and excess ^{210}Pb throughout all cores (~200 cm deep) examined to date (4 vibracores, with 4 more to be analyzed) indicating an age <55 y. Therefore, the minimum accumulation rate at these locations on the flat is ~4 cm/y. Measurements of integrated mud content on the flat generally reveal ~10% by mass. Our preliminary budget for mud flux into the flat is $\sim 2 \times 10^5$ tons/y. From interactions with sediment-transport studies (by Ogston), tidal reworking of the flat is documented to resuspend regularly the upper 2-3 cm of the flat surface and consequently wash out most of the ephemeral mud deposits. This resuspended fine sediment is transported seaward, especially during the ebb portion of spring tides. Cores collected in Saratoga Passage (Fig. 4) indicate $\sim 5 \times 10^5$ tons/y of fine sediment is accumulating there, and cores from north of the Skagit delta demonstrate that an additional amount of fine sediment moves toward and through Deception Pass.

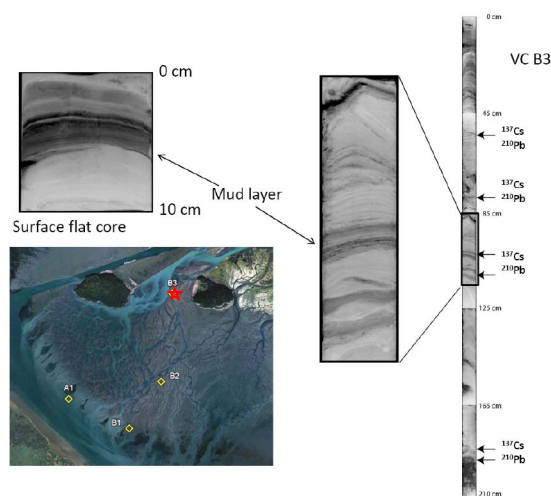


Fig. 3 – Sequence of x-radiographs (negatives) from tidal-flat vibracore (far right) and surface core (upper left); dark areas are muddy. The cores are primarily cross-bedded sand, with some muddy laminae. Even deep in core (~200 cm), the mud laminae contain ^{137}Cs and excess ^{210}Pb , indicating an age <55 y. This core was located near the North Fork (red star), and reflects rapid sediment burial by channel deposits.

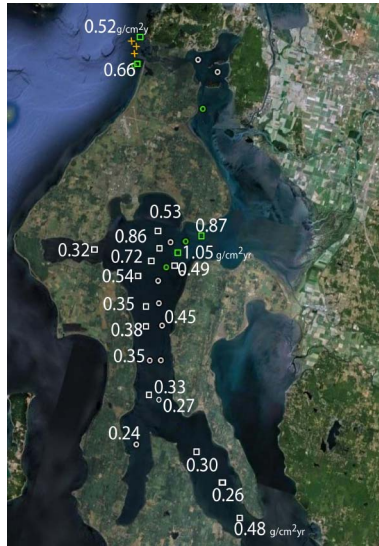


Fig. 4 – Mass accumulation rates ($\text{g}/\text{cm}^2/\text{y}$) for cores collected in Saratoga Passage, and a few cores from outside Deception Pass (to north). These cores contain almost entirely silt and clay (sand <2%), and indicate total accumulation in Saratoga Passage of $\sim 5 \times 10^5$ tons/y. Loss northward is more difficult to constrain, because sediments leaving Deception Pass are broadcast widely.

TRANSITIONS

Other investigators in the Tidal Flats DRI are transferring the results from this effort into their projects. Those studying the seabed incorporate radiochemical and textural data to document the processes (e.g., physical reworking, bioturbation) impacting seabed characteristics. Researchers analyzing boundary-layer processes also utilize these data to understand bed erosion and deposition. Accumulation rates, sediment budgets, and grain-size data are key components to input parameters for numerical models.

RELATED PROJECTS

Related projects include studies of: the seabed by R. Wheatcroft and P. Wiberg; boundary-layer processes by A. Ogston, R. Geyer, P. Traykovski, and D. Ralston; suspended-sediment dynamics by P. Hill, B. Law and T. Milligan; seabed thermal processes by J. Thomson and C. Chickadel.

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